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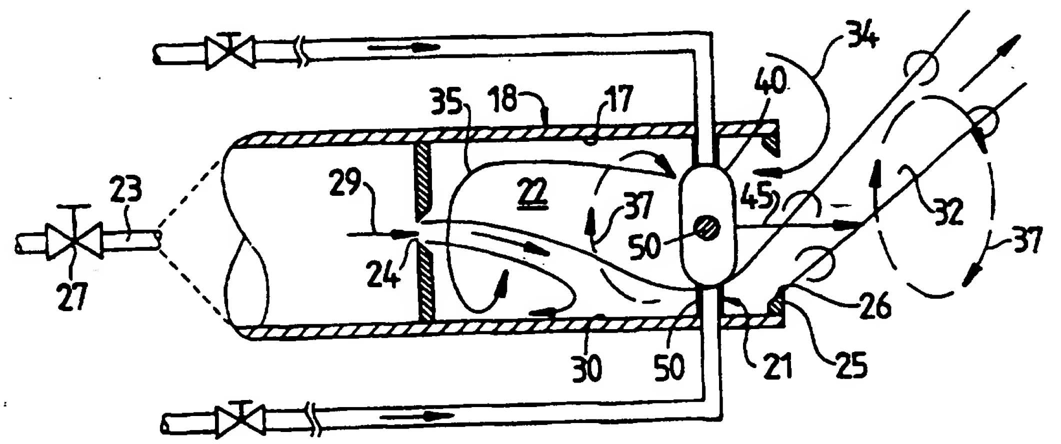
(54) Title: VARIABLE FLAME PRECESSING JET NOZZLE



(57) Abstract

A burner nozzle comprises a tubular body (18) defining a chamber (22). Fuel jet (29) enters at aperture (24) and is separated fr the chamber wall. The jet reattaches itself asymmetrically (30) to the inside wall surface (17). The jet precesses (37) about the nozzle a as it is deflected (32) when emerging from the outlet port (26). The precession enhances mixing of fuel with air (34, 35) from the exte of the chamber (22). Flow control means (40) directs further flow of fluid through an orifice. This flow forms a secondary jet (45) alig along the axis about which the primary jet precesses. The momentum of the secondary jet (45) influences flame shape. By controlling secondary jet, the overall flame shape can be controlled. A diversity of flame shapes, e.g. a short radiant flame or a long convective fla can be obtained.

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VARIABLE FLAME PRECESSING JET NOZZLE

This invention relates to a nozzle configuration and in preferred embodiments to a variable flame precessing jet burner nozzle. The invention has particular though certainly not exclusive application to a variable flame burner fuelled by natural gas and is applicable to kilns such as rotary cement kilns, furnaces and other process heating arrangements.

The present applicant's international patent publication WO88/08104 (PCT/AU88/00114), and the associated US patent 5060867 and Australian patent 614518, disclose a fluid mixing nozzle in which a primary flow of a first fluid separates from the internal wall structure and reattaches itself asymmetrically to the wall upstream of the nozzle outlet. A flow of a second fluid induced through the outlet swirls in the chamber between the flow separation and reattachment and induces precession of the separated reattached flow, which exits th nozzle asymmetrically. This nozzle has come to be termed a precessing jet nozzle and such terminology is adopted herein. A burner incorporating a precessing jet nozzle is variously referred to as a precessing jet burner or precessing jet nozzle burner. By the optional addition of a centre-body within the chamber, part of the primary flow can be caused to recirculate within the chamber and induce or stabilise the precession.

When the precessing jet nozzle is operated as a burner, using eg natural gas as the fuel and primary flow, it has been observed that, in comparison with a simple turbulent jet burner, the precessing jet nozzle generates a more bulbous flame whose stand-off distance is reduced by an order of magnitude and whose blow-off velocity is increased by a factor of four. These features have been found to enhance the stability and radiation characteristics of the flame in furnaces and boilers and to enhance the performance of kilns such as lime kilns and rotary cement kilns employed to produce cement clinker. Both the quality of the clinker produced in such kilns and the energy required to produce it, are significantly influenced by the "heat release profile" of the flame generated by the burner and

by the proportion of the energy which is radiated, as opposed to being convected, to the product. The heat release profile of the flame is the proportion of the total energy which is released in each part of the kiln, and it will thus be appreciated that the precessing jet burner, with its closer bulbous flame and higher blow-off velocity, is well suited in principle to kiln application.

It was found that a precessing jet nozzle burner in a cement kiln resulted in a reduction in NO_x emissions by up to 75% relative to a more conventional turbulent jet burner, and moreover benefited the clinkering process. However, the flame was found to release too much heat at the front of the kiln during some phases of the kiln operation, which adversely affected the life of the refractory bricks. Similar constraints were anticipated in some applications of the precessing jet nozzle burner to other direct process heating in, for example, the metals, glass and chemical industries. One approach to this problem is disclosed in the present applicant's international patent publication WO94/07086 [PCT/AU93/00476], and entails a burner configuration including at least one precessing jet nozzle and at least one further burner nozzle having mixing characteristics different from the precessing jet nozzle. The nozzles of the set are preferably in sufficient proximity that the combined flame of the burner configuration can be determined or controlled by setting or varying the relative flows of fuel to the nozzles. The further nozzle may be a simple turbulent jet nozzle, eg a straight pipe nozzle, whereby the precessing jet nozzle produces a flame which is relatively shorter and more radiant and the flame of the further nozzle is relatively longer and more convective.

According to the invention, there is provided a precessing jet burner nozzle comprising:

a body including a chamber which includes a fluid inlet and a fluid outlet displaced from the inlet in a longitudinal direction of said chamber, which body is configured such that a primary flow of a first fluid into said chamber through said inlet separates from the internal wall of the chamber and reattaches itself asymmetrically to the wall of the chamber from the nozzle outl t, a flow of a second fluid induced through the outlet swirling in the chamber between the flow

separation and reattachment and inducing precession of the separated reattache flow, which exits the chamber asymmetrically through said outlet; and

flame control means for controlling the shape of the flame produced by th burner, said flame control means comprising structure disposed generally centrall in said chamber between said inlet and said outlet to reduce the cross-section o said chamber transverse to said longitudinal direction while allowing said precessin flow to precess about said structure, at least one orifice associated with sai structure for delivering a jet of fluid to said chamber towards said outlet, duc means to deliver fluid to the or each said orifice, and flow control means fo controlling the relative fluid flows of said precessing fluid and the fluid discharge through the or each said orifice, the flame control means being such that the o each jet of fluid forms a secondary jet along an axis generally aligned with an axi about which precession occurs whereby the momentum of the second jet influence the shape of the flame.

The nozzle including the chamber, is preferably axisymmetric. The structur preferably comprises a body which is coaxial with said body and said chamber. Th chamber may be cylindrical and the chamber cross-section about the body may b annular.

In the absence of further flow from said structure, the precession of the je emerging from the precessing jet nozzle causes mainly large scale mixing of the je with the surrounding fluid, and a low pressure along the axis about which the je precesses so inducing a reversed flow along said axis towards said nozzl outlet. B admitting said further flow of fluid through said outlet from said structure sai reversed flow along said axis is inhibited. The fluids comprise one or more fuel and by adjusting the proportions of the fuel flows through the main inlet and as th further flow of fluid, the mixing characteristics and hence the resulting flame shap can be modified. It will be appreciated that, by adjustment of appropriate flo control means, the ratio of the total flow which is introduced thr ugh th ma intake and as the further flow of fluid can be varied so that the heat r l ase profi of the resultant flame can be tailored to the current requirements of the kiln

other process.

In an embodiment, the precessing jet burner nozzle of the invention may be provided in combination with at least one further burner nozzle have mixing characteristics different from the precessing jet nozzle, the nozzles preferably being in sufficient proximity that the combined flame of the burner configuration can be determined or controlled by setting or varying the relative flows of fuel to the nozzles. The further nozzle may be a simple turbulent jet nozzle, eg a straight pipe nozzle, whereby the precessing jet nozzle produces a flame which is relatively shorter and more radiant and the flame of the further nozzle is relatively longer and more convective. In a convenient form of this embodiment, one of the nozzles may be disposed about the other in a coaxial annular configuration.

In the attached drawings:-

Figure 1 schematically depicts a simple precessing jet burner nozzle configuration with a centrebody structure through which one or more fluids may be injected as a secondary jet aligned along the axis about which the primary jet precesses, according to an embodiment of the invention; and

Figure 2 is a diagrammatic cross-section of the burner configuration of Figure 1, including a simple flow representation of the instantaneous pattern of the three-dimensional dynamically precessing and swirling flow thought to exist in and around the precessing jet nozzle once mixing has become established and the secondary jet directed along the axis of precession has been activated.

The burner configuration 10 illustrated in Figure 1 comprises a precessing jet (PJ) nozzle 20 which includes a tubular body 18 defining an axisymmetric generally cylindrical chamber 22. Chamber 22 has a simple inlet aperture 24 in a rear partition 19 of body 18 defining a sudden expansion for a first flow 29 at the chamber's inlet end, and a small peripheral lip 25 defining an outlet port 26. Structure in the form f a transversely disposed disc-like centre body 40 is disposed

in chamber 22 upstream of outlet port 26, relatively much closer to port 26 than to inlet aperture 24, and has an orifice 42 from a duct system 44 within body 40 from which a further flow 45 of fluid is directed towards and through outlet port 26. It will be appreciated that inlet aperture 24, chamber 22, outlet port 26, center-body 40 and orifice 42 are generally coaxial. Centre-body 40 defines a restricted annular cross-section 21 of chamber 22.

In operation, fuel jet 29 enters chamber 22 at aperture 24, from a delivery line 23 via control valve 27, and is there separated from the chamber wall. The jet then reattaches asymmetrically at 30 (Figure 2) to the inside wall surface 17 of tubular body 18 and at the outlet port 26 is deflected (32) at a large angle (eg 45°) from the nozzle axis by strong local pressure gradients. There are also strong azimuthal pressure gradients which cause the jet, and the entire flow field within the chamber, to precess (represented at 37) about the nozzle axis and about centre-body 40. These pressure gradients and fields induce a reverse flow of air 34 through the outlet 26 and this air swirls in the chamber at 35 between the flow separation and the reattachment and in part induces the precession of the separated/reattached flow. This precession enhances mixing of the fuel flow with the air from the exterior of the chamber. Centre-body 40 is effective to reduce the cross-section of chamber 22 transverse to the longitudinal or axial direction while allowing the precessing flow to precess about the centre-body through annular cross-section 21. The flow emerging from orifice 42 forms a secondary jet aligned along the axis about which the primary jet precesses. This jet has a relatively high momentum, which can be employed to change the shape of the flame which results when the arrangement is used as a burner. Moreover, by admitting this further flow through orifice 42, reverse flow along the axis is inhibited.

Further particulars and embodiments of precessing jet nozzles are disclosed in international patent publication WO88/08104 (PCT/AU88/00114) and in the associated national and regional patent publications including US patent 5060867. The contents of these documents are incorporated herein by reference.

Typically, centre-body 40 is supported by radial legs or webs 50 secured to the internal wall 17 f chamber 22. At least one of these legs or webs incorporates a duct 52, or indeed comprises a rigid tube, by which fluid such as a fuel may be delivered to orifice 42 via feed line 53 and control valve 54. Optionally, more than one different fluid can be delivered to orifice 42 by respective feed lines 53,53a and valves 54,54a. In this option, the different fluids can be fed to the same orifice or to different orifices. In the latter case the jets from the different orifices will coalesce to form the secondary jet.

The ratio of the total fluid flows which are supplied to inlet aperture 24 and orifice 42 can be controlled by means of valves 27,54 (and/or other flow blockage device, or by means of variable capacity pumps), so that any combination of flows can be achieved, thereby enabling a diversity of flames, whose characteristics vary between that of a precessing jet flame and that of a "conventional" flame, to be selected.

The types of fluids which can be introduced through the main PJ nozzle and through, or in front of, the centre-body may be similar or different. In combustion applications the fluids through either channel include, but are not restricted to, gaseous fuels, air, oxygen, heavy or light fuel oil and flue gases.

The shape of the one (or more) orifices 42 in the centre-body 40, through which fluid(s) is/are introduced into the external flow includes, but is not restricted to, round, square, rectangular, petal shaped, star shaped, oval and annular. The transition from within said centrebody to said orifice 42 may be smooth or abrupt.

The illustrated assembly may be manufactured as a single component, in which case the centre-body is hollow and the fluid is conveyed through it. Alternatively the jet may be introduced downstream from the centre-body through at least one separate nozzle. Fluids may be mixed within the centre-body or the downstream nozzle, or they may be introduced as separate flows which mix downstream fr m the nozzles.

The shape of the flow passage or duct system within the centre-body, or through the at least one separate nozzle, may be such as to cause the fluids to mix within the centre-body or separate nozzle, or to mix after leaving the centre-body or separate nozzles. Swirl may be imparted to the fluids within the centre-body or separate nozzles.

By relative adjustment of valves 27,54,54a using any suitable control means, which may be manual, the proportions of fuel flow to th respective apertures/orifices can be varied so that the combined flame and the resultant heat release profile of the combined flame can be tailored to the requirements of the kiln. In the case of a cement clinker kiln, it is found that, not only does the burner configuration of Figure 1 enable the combined flame to be controlled to suit the given type of cement clinker, it also enables greater control of the kiln to be achieved and facilitates the relatively easy removal of rings of coating which occasionally form. To explain this latter point further, the clinker in the burning zone within the kiln, ie where the clinker undergoes the exothermic clinkering reaction and reaches its maximum temperature, is sticky and forms a coating on the refractory brick lining within the kiln. This is an advantage to the operation since the coating acts as an insulating layer which protects the bricks. However, under some conditions an annular ring of coating can develop which causes the clinker to build up behind it. If the ring breaks, a rush of clinker through the kiln can cause serious problems and may result in damage to the plant. The development of ring is related to the heat release profile, so that the ability to vary that profile during operation with a burner configuration according to the invention facilitate the early removal of a ring before it becomes a problem.

A particular application of the illustrated variable center-body burner is welding or brazing torch which combines the functions of a zone heating flan (used to pre-heat the metal) and a high temperature, high momentum welding brazing flame. In such an application the fuels for the two flames could different. For example a readily available form f petroleum gas, such as natur gas r propane, could be used for the zone heating duty, while acetylene, mix

with oxygen within the centre-body, could be used for the zone welding or brazing duty.

A further application for the proposed variable centre-body burner is to facilitate the use of different fuels. Examples are, but are not limited to, the use of gas through the main precessing jet burner, supplemented by oil from an atomising nozzle in the centre-body. The oil may be atomised by any means, one of which may include an air-blast atomiser, supplied through a separate feed line to the centre-body.

It is emphasised that the illustrated flow control means comprising valves 27,54,54a etc is only one of a variety of possible arrangements for varying the ratio of flows. For example, when the pressure drops through each of the two apertures or orifices are approximately the same, a single valve may be used to control the ratio of flows.

Throughout this specification, unless the context requires otherwise, the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

The described arrangement has been advanced merely by way of explanation and many modifications may be made thereto without departing from the spirit and scope of the invention which includes every novel feature and combination of novel features herein disclosed.

CLAIMS:

1. A precessing jet burner nozzle comprising:

a body including a chamber which includes a fluid inlet and a fluid outlet displaced from the inlet in a longitudinal direction of said chamber, which body is configured such that a primary flow of a first fluid into said chamber through said inlet separates from the internal wall of the chamber and reattaches itself asymmetrically to the wall of the chamber from the nozzle outlet, a flow of a second fluid induced through the outlet swirling in the chamber between the flow separation and reattachment and inducing precession of the separated reattached flow, which exits the chamber asymmetrically through said outlet; and

flame control means for controlling the shape of the flame produced by the burner, said flame control means comprising structure disposed generally centrally in said chamber between said inlet and said outlet to reduce the cross-section of said chamber transverse to said longitudinal direction while allowing said precessing flow to precess about said structure, at least one orifice associated with said structure for delivering a jet of fluid to said chamber towards said outlet, duct means to deliver fluid to the or each said orifice, and flow control means for controlling the relative fluid flows of said precessing fluid and the fluid discharged through the or each said orifice, the flame control means being such that the or each jet of fluid forms a secondary jet along an axis generally aligned with an axis about which precession occurs whereby the momentum of the second jet influences the shape of the flame.

2. A burner nozzle according to claim 1, wherein said structur comprises a body which is coaxial with the chamber.

3. A burner nozzle according to claim 2, wherein the chamber is cylindrical anc the body is located within said chamber such that a passage of annular shape is defined between the body and the wall of the chamber.

4. A burner nozzle according t claim 3, wherein the or ach said orifice i

formed in the body.

5. A burner nozzle according to claim 3, wherein the or each said orifice is formed in a nozzle carried by the body.

6. A burner nozzle according to any one of claims 1 to 5, wherein the duct means is operative to deliver at least two fluids to the orifice.

7. A burner nozzle according to claim 6, wherein the fluids are mixed prior to discharge through the orifice.

8. A burner nozzle according to claim 6, wherein the fluids are mixed after discharge from the orifice.

9. A burner nozzle according to any one of claims 1 to 8, comprising means for inducing swirl to one or more of said fluids prior to discharge from the orifice.

10. A burner nozzle according to any one of claims 1 to 9, wherein said structure is supported from the wall of the chamber by a support which includes said duct means.

11. A burner nozzle according to any one of claims 1 to 10, wherein the fluid control means comprises means to control the fluid flow through the duct means whereby to control the momentum of the secondary jet.

12. A burner nozzle according to any one of claims 1 to 11, wherein the orifice is of a shape selected from the group consisting of round, square, rectangular, petal shaped, star shaped, oval or annular.

13. A burner nozzle according to any one of claims 1 to 12 in combination with at least ne further nozzle, the burner nozzle and said further nozzle being in sufficient proximity that the said burner nozzle and further nozzle produce a

combined flame, said combination further comprising means for controlling the relative flows through the burner nozzle and further nozzle.

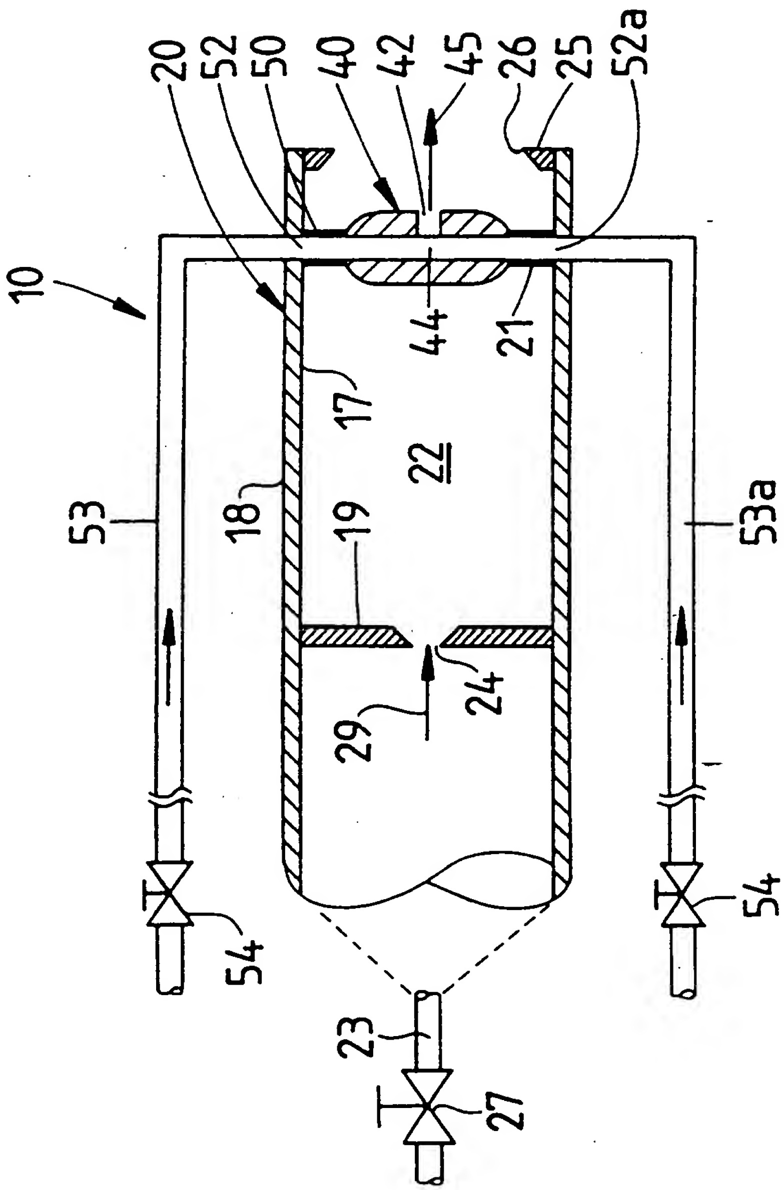
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FIG 1

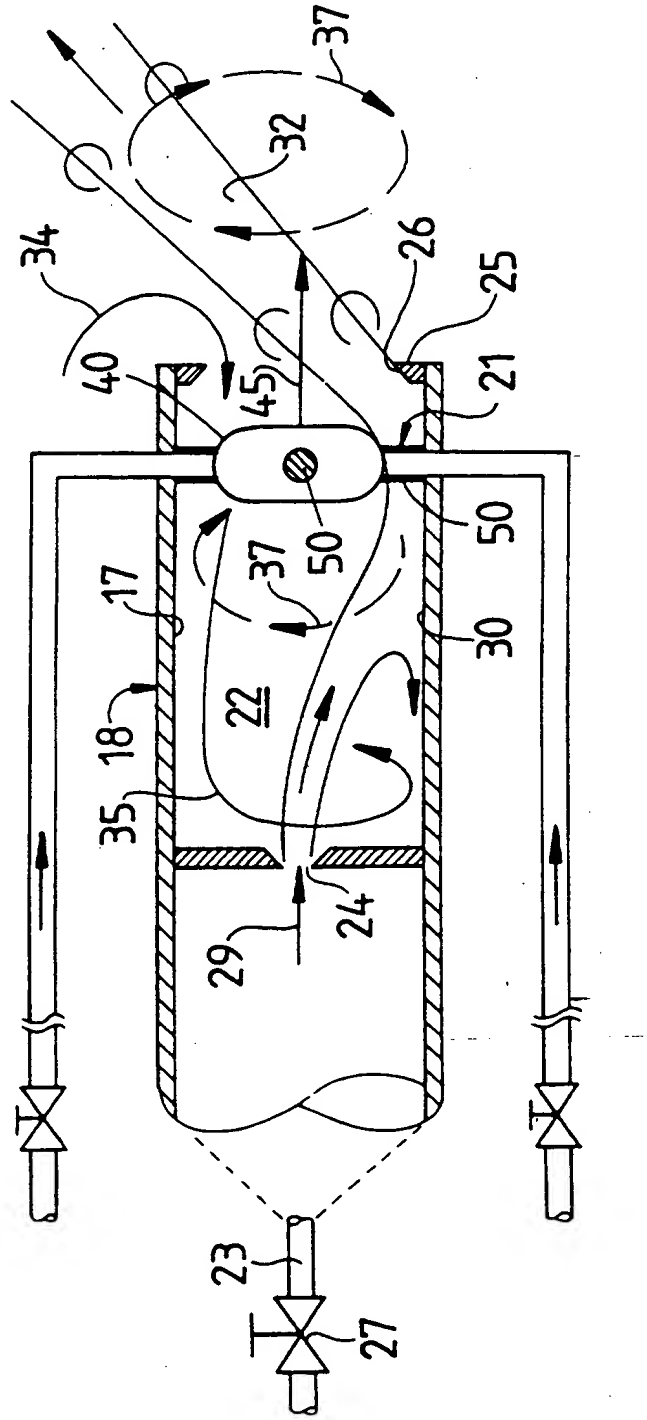

FIG 2

INTERNATIONAL SEARCH REPORT

International Appli
PCT/AU 96/00115

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl[6]: F23D 14/48, 14/84, 14/70, 14/62, 14/58 // F23C 5/08, 5/32

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC : F23D 14/48, 14/84, 14/70, 14/62, 14/58, 14/04, 23/00, 13/34

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU : IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPAT, JAPIO - F23D 14/48, 14/84, 14/70, 14/62, 14/58, 14/04, 23/00, 13/34
Full search and also with keywords COANDA (W) EFFECT: OR PRECES: OR SWIRL:

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No
Y	US 5060867 A (LUXTON et al) 29 October 1991. Figure 2c; column 7, line 67 - column 8, line 27.	1-13
Y	WO 94/07086 A (LUMINIS PTY LTD) 31 March 1994. Page 2, line 19 - page 3, line 24; page 6, line 20 - page 6, line 22; figures 3-6.	1-13
A	US 3954382 A (HIROSE) 04 May 1976. Figures 1-4; column 2, line 67 - column 3, line 10.	1

☐ Further documents are listed in the continuation of Box C

☒ See patent family annex

* Special categories of cited documents:

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 April 1996	8TH. MAY 1996.

Name and mailing address of the ISA/AU	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No.
PCT/AU 96/00115

This Annex lists the known "A" publication level patent family members relating to the patent documents cite in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	5060867	AT	102503	AU	16235/88	CA	1288420
		CN	1032385	DE	3888222	DK	5124/89
		EP	287392	ES	2049747	IN	170251
		JP	2-503947	NO	885569	WO	88/08104
WO	94/07086	EP	662208	NZ	255966	AU	48107/93
US	3954382	JP	50-132534				

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